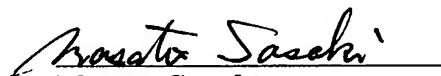


DECLARATION

I, Masato Sasaki, c/o Fukami Patent Office, Nakanoshima Central Tower, 22nd Floor, 2-7, Nakanoshima 2-chome, Kita-ku, Osaka-shi, Osaka, Japan, declare:

that I know well both the Japanese and English languages;
that to the best of my knowledge and belief the English translation attached hereto is a true and correct translation of Japanese Patent Application No. 2004-040085, filed on February 17, 2004;
that all statements made of my own knowledge are true;
that all statements made on information and belief are believed to be true;
and
that the statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001.

Dated: April 2, 2009


Masato Sasaki

| | |
|--------------------------|---|
| [Document Name] | Petition for Patent |
| [Reference Number] | 1032386 |
| [Filing Date] | February 17, 2004 |
| [Destination] | To the Commissioner of the JPO |
| [International Class] | F16H 9/18 |
| [Inventor] | |
| [Address] | c/o NTN Corporation, 1578, Higashikaizuka, Iwata-shi, Shizuoka |
| [Name] | Kousuke OBAYASHI |
| [Applicant] | |
| [Identification Number] | 000102692 |
| [Address] | 3-17, Kyomachibori 1-chome, Nishi-ku, Osaka-shi |
| [Name] | NTN Corporation |
| [Attorney] | |
| [Identification Number] | 100064746 |
| [Patent Attorney] | |
| [Name] | Hisao FUKAMI |
| [Appointed Attorney] | |
| [Identification Number] | 100085132 |
| [Patent Attorney] | |
| [Name] | Toshio MORITA |
| [Appointed Attorney] | |
| [Identification Number] | 100083703 |
| [Patent Attorney] | |
| [Name] | Gihei NAKAMURA |
| [Appointed Attorney] | |
| [Identification Number] | 100096781 |
| [Patent Attorney] | |
| [Name] | Yutaka HORII |
| [Appointed Attorney] | |
| [Identification Number] | 100098316 |
| [Patent Attorney] | |
| [Name] | Hisato NODA |
| [Appointed Attorney] | |
| [Identification Number] | 100109162 |
| [Patent Attorney] | |
| [Name] | Masayuki SAKAI |
| [Appointed Attorney] | |
| [Identification Number] | 100111936 |
| [Patent Attorney] | |
| [Name] | Seiichi WATANABE |
| [Indication of Fee] | |
| [Deposit Account Number] | 008693 |
| [Fee] | 21000 |

[List of the Accompanying Documents]

| | | |
|------------|---------------|---|
| [Document] | Specification | 1 |
| [Document] | Drawings | 1 |
| [Document] | Abstract | 1 |

[Document Name] Scope of Claims for Patent

[Claim 1] A support structure for a continuously variable transmission in which rotation of an input shaft is changed in a nonstep manner and transmitted to an output shaft, including

a thrust needle roller bearing receiving thrust load generated by the rotation either of said input shaft or said output shaft, having a washer formed of a thin steel plate and a needle roller, wherein at least said washer has a nitrogen enriched layer at a surface layer portion, amount of retained austenite in said surface layer portion is at least 5 volume % and at most 25 volume %, and austenite grain size number of said surface layer portion is 11 or higher.

[Claim 2] The support structure for a continuously variable transmission according to claim 1, wherein nitrogen content of said surface layer portion is in the range of 0.1 mass % to 0.7 mass %.

[Document Name] Specification

[Title of the Invention] Support Structure for Continuously Variable Transmission

[Technical Field]

[0001]

The present invention relates to a support structure for continuously variable transmission and, more specifically, to a long life support structure for a continuously variable transmission, of which thrust needle roller bearing is resistant to an early failure caused by surface damage such as surface-originated flaking and resistant also to common load-dependent rolling contact fatigue.

[Background Art]

[0002]

A thrust needle roller bearing consists of needle rollers, a cage and a washer, in which the needle rollers are in line-contact with the washer. Therefore, the bearing advantageously attains high load carrying capacity and high rigidity, for its small projection area. Therefore, a thrust needle roller bearing is suitable as a bearing used under severe conditions of low viscosity lubrication or high-speed rotation, and it is used for a support structure for continuously variable transmission of automatic vehicle.

[0003]

Such a thrust needle roller bearing is disclosed, for example, in Patent Document 1 (Japanese Patent Laying-Open No. 2002-70872).

[0004]

Conventionally, auto manufacturers and manufacturers of automatic transmissions sometimes use oil with an additive, in view of energy saving. The oil with such an additive has lower lubrication performance on the bearing, and therefore, improvement of existing thrust bearings involving much differential slip at the rollers has been desired, from the viewpoint of surface damage such as surface-originated flaking.

[0005]

There is a tendency that automatic transmissions are used under higher load, and

therefore, improvement of existing bearings is also desirable from the viewpoint of subsurface-originated flaking caused by common load-dependent rolling contact fatigue.

[0006]

Therefore, a bearing of long life that is resistant to an early failure caused by surface damage such as surface-originated flaking and resistant also to subsurface-originated flaking caused by common load-dependent rolling contact fatigue is desired.

[Patent Document 1] Japanese Patent Laying-Open No. 2002-70872

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0007]

Conventionally, as a material for the washer of a thrust needle roller bearing, readily processable and available steel plate and steel tape material that allows press-processing, including low carbon structural steel, cold-rolled steel plate, steel tape, medium carbon steel or bearing steel has been used. When low carbon structural steel, cold-rolled steel plate or steel tape is used, carburization or carbonitriding process is performed as heat treatment of the washer, and when medium carbon steel or bearing steel is used, bright quenching or induction hardening is performed.

[0008]

Bearing steel is used as the material of the roller of a conventional thrust needle roller bearing, and bright quenching or quench hardening is performed as heat treatment.

[0009]

In a thrust needle roller bearing, heat caused by differential slip at the roller may induce damage such as surface-originated flaking. Enforcement of the washer against the surface damage including the surface-originated flaking is desired.

[0010]

Further, under heavy load conditions, subsurface-originated flaking also occurs because of common load-dependent rolling contact fatigue, and longer life is desired.

[0011]

The present invention was made in view of the foregoing and its object is to provide a long life support structure for continuously variable transmission, of which thrust needle roller bearing is resistant to an early failure caused by surface damage such as surface-originated flaking and resistant also to common load-dependent rolling contact fatigue.

[Means for Solving the Problems]

[0012]

The support structure for a continuously variable transmission in accordance with the present invention is a support structure for a continuously variable transmission in which rotation of an input shaft is changed in a nonstep manner and transmitted to an output shaft. A thrust needle roller bearing receiving thrust load generated by the rotation either of the input shaft or the output shaft has a washer formed of a thin steel plate and needle rollers, at least the washer has a nitrogen enriched layer at a surface layer portion, amount of retained austenite in the surface layer portion is at least 5 volume % and at most 25 volume %, and austenite grain size number of the surface layer portion is 11 or higher.

[0013]

In the support structure for a continuously variable transmission, preferably, nitrogen content of the surface layer portion of the thrust needle roller bearing is in the range of 0.1 mass % to 0.7 mass %.

[0014]

In the support structure for a continuously variable transmission in accordance with the present invention, the washer material of the thrust needle roller bearing is adapted to have fine crystal grain size and high heat resistance, and therefore, life defined by surface-originated flaking (surface damage such as peeling and smearing) and life defined by subsurface-originated flaking can both be improved.

[0015]

Specifically, by devising and adjusting processing and heat treatment of the

material such as bearing steel and medium carbon steel, a carbonitrided texture (nitrogen enriched layer) reliably having austenite grain size number of 11 or higher can be obtained. This texture significantly increases resistance to generation and development of cracks. As a result, heat generation at a surface layer caused by slipping or surface cracks caused by tangential force can be suppressed. Further, the inventors have found that significantly longer life can be attained as regards cracks caused by subsurface-originated flaking.

[0016]

Considering the surface damage such as the surface-originated flaking, it is particularly essential that a heat-resistant, nitrogen enriched layer having fine carbide deposited at the surface layer portion is formed. In the present invention, a nitrogen enriched layer is formed, and in addition, at least 5 volume % of retained austenite exists at the surface layer portion and the austenite at the surface layer portion is as fine as to have austenite grain size number of 11 or higher. Thus, surface damage such as surface-originated flaking can be suppressed.

[0017]

The retained austenite existing in the nitrogen enriched layer at the surface layer portion is a factor that decreases surface hardness. Therefore, it is necessary to decrease the amount of retained austenite than a carbonitrided article, through quenching after carbonitriding process, by re-heating to a temperature lower than the temperature of carbonitriding process. In the present invention, the retained austenite at the surface layer portion is reduced to 25 volume % or lower, and therefore, decrease in surface hardness can be suppressed.

[0018]

With the above-described micro-texture as a basic component, further processing or heat treatment is performed to exert compressive stress on the surface layer described above, to further increase hardness, whereby longer life can be attained. As the processing or heat treatment, a technique such as (b1) shot peening, (b2)

barreling, (b3) rolling, (b4) carburization + carbonitriding, (b5) carbonitriding + sub zero treatment or (b6) carbonitriding + secondary quenching + sub zero treatment may be applied by itself, or combination of techniques (b1) to (b6) may be applied.

[0019]

At least one of the washer and the roller may be subjected to the carbonitriding process at A_1 transformation point or higher, cooled to a temperature lower than the A_1 transformation point, thereafter heated to a quenching temperature lower than the temperature of carbonitriding process, and then quenched from that quenching temperature.

[0020]

In the process of cooling to a temperature lower than the A_1 point after carbonitriding at the carbonitriding temperature, the temperature may be lowered to room temperature by oil quenching, or cooled to a temperature at which austenite transformation is completed at least to a prescribed value. By the manufacturing method described above, a metal texture having a nitrogen enriched layer, fine austenite grains and containing appropriate amount of retained austenite can be obtained. Consequently, life defined by surface-originated flaking and life defined by subsurface-originated flaking can both be improved. Further, a thrust needle roller bearing of which dimensional variation with aging is suppressed can be provided. As a result, a support structure for continuously variable transmission having long life can be provided.

[0021]

As described above, the nitrogen enriched layer is formed by carbonitriding process, and the nitrogen enriched layer may or may not be carbon-enriched.

[0022]

In such a micro-texture, very fine austenite crystal grains can be obtained, as it is once cooled after carbonitriding process and quenched from a quenching temperature lower than the temperature of carbonitriding process. The process of heating to the quenching temperature lower than the temperature of carbonitriding process and

quenching is sometimes referred to as secondary quenching or final quenching, in view of the order of processing.

[0023]

The quenching temperature mentioned above may be in a temperature range where carbide and/or nitride and austenite phase co-exist at least in the surface layer portion of the carbonitrided steel.

[0024]

As the heating temperature at the time of quenching is lower than the heating temperature of carbonitriding process, the amount of carbide and/or nitride not-yet-absorbed at the surface layer portion subject to the effect of carbonitriding process is increased than in the carbonitriding process. Therefore, when the quenching temperature is in the above-described co-existing temperature range, the ratio of not-yet-absorbed carbide/nitride at the quenching temperature is increased than in the carbonitriding process, and the ratio of austenite amount decreases. Further, it can be seen from the binary phase diagram of iron-carbon, in the region where carbide (cementite) and austenite co-exist, that concentration of carbon contained as solid solution in austenite decreases as the quenching temperature decreases. The steel used for a bearing has low content of other alloy element such as Si (silicon) or Mn (manganese) and, therefore, it is possible with sufficiently high accuracy to discuss temperature ranges and generated layers, using the iron-carbon binary phase diagram. Further, similar to carbon, nitrogen is contained as interstitial solid solution in iron, and generates nitride with iron similar to cementite in a prescribed temperature range. Therefore, it can be regarded as the same as carbon, in approximation.

[0025]

When heated to the quenching temperature, there is a large amount of carbide and/or nitride that is not yet absorbed and prevents growth of austenite grains, and hence, the austenite grains come to be very fine. Further, the texture transformed by quenching from austenite to martensite has slightly lower carbon concentration when

subjected to the heat treatment described above, and therefore, the texture comes to have slightly higher toughness than the texture quenched from the carbonitriding temperature. Specifically, the quenched texture comes to have (c1) not-yet-absorbed carbide and/or nitride of larger amount than the conventional example and (c2) carbon concentration lower than the conventional example.

[0026]

The quenching temperature mentioned above may be set to 780°C to 830°C. This temperature range may be applied to almost every steel material, so that management of quenching temperature is simplified.

[0027]

Further, at least one of the washer and roller described above may be subjected to cold working such as pressing, prior to the carbonitriding process.

[0028]

By performing such cold working, nucleation density of austenite grains at the time of heat treatment increases, and very fine texture can be obtained.

[0029]

Further, to at least one of the washer and the roller described above, compressive stress of at least 500 MPa may be applied.

[0030]

As already described, with the above-described micro-texture as a basic component, further processing or heat treatment may be performed to exert compressive stress on the surface layer described above, whereby longer life can be attained.

[0031]

In the present specification, austenite grain size number refers to the grain size number of austenite defined by the method of austenite grain size determination in accordance with JIS G 0551.

[0032]

In the present specification, the austenite grain refers to austenite crystal grain

that is phase-transformed during quenching, and refers to the one remaining even after transformation by cooling to martensite, as the past history.

[0033]

The austenite crystal grains should have grain boundary that can be observed by performing a process such as etching to expose the grain boundary on a metallographic sample of the object member. The grains are also referred to as old austenite grains, meaning the grain boundary at a heated time point immediately before low-temperature quenching. As to the measurement, an average value of grain numbers of JIS standard may be converted as an equivalent to the average grain diameter, or a section method or the like may be used, in which an average of distances at which straight lines in random direction overlapped on the metallographic sample meet the grain boundary is calculated and multiplied by a correction coefficient to obtain the two-dimensional to three-dimensional distance.

[0034]

The retained austenite is measured using various X-ray diffraction methods, in which, by way of example, diffraction intensity of appropriate Miller indices of the austenite phase is found, and compared with diffraction intensity of appropriate Miller indices of the ferrite phase. At this time, height of diffraction peak may be used, or area of diffraction peak may be used. Alternatively, it can be measured utilizing the fact that the austenite phase is non-magnetic and the ferrite phase is ferromagnetic, by finding magnetizing force using a magnetic balance. It can also be measured easily by a commercially available measuring device.

[0035]

At the time of low temperature quenching, the austenite phase transforms to martensite and the like. The retained austenite refers to austenite left untransformed after the temperature is cooled to the room temperature, between adjacent martensite bundles or the like that transform along different crystal faces. Therefore, it is not directly related to the austenite crystal grains of which range of average grain size is

limited as described above.

[0036]

It is not effective when the nitrogen content at the surface layer portion is smaller than 0.1 mass %, and rolling contact fatigue life decreases particularly in the presence of foreign matters. When the nitrogen content is larger than 0.7 mass %, pores referred to as voids are generated, or the amount of retained austenite becomes too large to attain sufficient hardness, so that the life becomes shorter. The nitrogen content of the nitrogen enriched layer formed in the washer is represented by a value at the surface layer of 50 μm from the surface of washer after grinding, which may be measured by an EPMA (Electron Probe Micro-Analysis).

[Best Modes for Carrying Out the Invention]

[0037]

Embodiments of the present invention will be described with reference to the figures.

[0038]

(Embodiment 1)

Fig. 1 is a schematic cross sectional view showing a support structure for a continuously variable transmission in accordance with Embodiment 1 of the present invention. Referring to Fig. 1, a driving force generated by an engine (not shown) is transmitted from a crank shaft (not shown) through a torque converter (not shown) and a forward/backward switching mechanism 110 to a continuously variable transmission 100.

[0039]

Forward/backward switching mechanism 110 has a planetary gear mechanism and multiple disk clutches 115, 116. Planetary gear mechanism has a ring gear 113a fixed on a shaft 101a through a support member 113, a sun gear 101b fixed on a primary shaft 101, and a planetary pinion 112a rotatably supported on a support member 112. Planetary pinion 112a engages with each of ring gear 113a and sun gear 101b.

[0040]

Multiple disk clutch 115 is mounted as a backward brake between an outer circumference of support member 112 and a housing 106. Multiple disk clutch 116 is mounted as a forward clutch between an outer circumference of primary shaft 101 and an inner circumference of support member 113. A mechanism (not shown) that can apply hydraulic pressure to each of multiple disk clutches 115 and 116 is provided.

[0041]

When hydraulic pressure is applied and multiple disk clutch (forward clutch) 116 is set to the connected state, rotation of shaft 101a is transmitted in a forward direction to primary shaft 101. When hydraulic pressure is applied and multiple disk clutch (backward brake) 115 is set to the connected state, rotation of shaft 101a is transmitted in a backward direction to primary shaft 101. This enables forward/backward motion control.

[0042]

Nonstep variable speed gear 100 has an input side primary shaft 101 coupled to forward/backward switching mechanism 110, a primary pulley 102 provided on primary shaft 101, an output side secondary shaft 103 parallel to primary shaft 101, a secondary pulley 104 provided on secondary shaft 103, and a belt 105 wound around both primary and secondary pulleys 102 and 104.

[0043]

Primary pulley 102 has a fixed pulley 102a fixed on primary shaft 101, and a movable pulley 102b mounted slideable along the axial direction on primary shaft 101 by means of a ball spline or the like. By the sliding of movable pulley 102b in the axial direction, an interval between cone surfaces of the pulley, that is, a pulley groove width, can be varied.

[0044]

Secondary pulley 104 has a fixed pulley 104a fixed on secondary shaft 103, and a movable pulley 104b mounted slideable along the axial direction on secondary shaft 104b

by means of a ball spline or the like. By the sliding of movable pulley 104b in the axial direction, an interval between cone surfaces of the pulley, that is, a pulley groove width, can be varied.

[0045]

By changing the groove width of both pulleys, contact diameter of belt 105 with pulley 102 and with pulley 104 changes. Consequently, the ratio of winding diameter of belt 105 around pulleys 102 and 104 changes. Thus, the rotation of primary shaft 101 is transmitted to secondary shaft 103 with the speed changed in stepless manner.

[0046]

In the present embodiment, thrust needle roller bearing 10 is provided to receive thrust load on input side shaft 101a and primary shaft 101 as well as output side secondary shaft 103.

[0047]

Fig. 2 is a cross sectional view showing, in enlargement, the portion P of Fig. 1, illustrating how the thrust needle roller bearing is arranged. Referring to Fig. 2, thrust needle roller bearing 10 is arranged, for example, between an inner ring of roller bearing 111 rotatably supporting primary shaft 101 and support member 112, between support member 112 and sun gear 101b, between sun gear 101b and support member 113, and between support member 113 and housing 106. Each thrust needle roller bearing 10 has needle rollers 2 and two cages 3, 4 for holding needle rollers 2. The needle rollers include needle rollers 2a, 2b in a plurality of rows.

[0048]

In the following, a specific structure of thrust needle roller bearing 10 will be described.

[0049]

Fig. 3 is a schematic cross sectional view showing a structure of a thrust needle roller bearing in accordance with Embodiment 1 of the present invention. Referring to Fig. 3, the thrust needle roller bearing 10A that corresponds to the thrust needle roller

bearing 10 of Figs. 1 and 2 has a pair of washers 1, 1, formed of thin steel plates, a plurality of needle rollers rolling between the pair of washers 1, 1, and an annular cage 3 holding the plurality of needle rollers 2 at a prescribed pitch along the circumferential direction. Washer 1 has a through hole 1a at the central portion, for inserting a shaft or the like.

[0050]

At least washer 1 of thrust needle roller bearing 10A has a nitrogen enriched layer at a surface layer portion, the amount of retained austenite at the surface layer portion is at least 5 volume % and at most 25 volume %, and the austenite grain size number at the surface layer portion is 11 or larger. Preferably, nitrogen concentration at the surface layer portion is at least 0.05 mass % and at most 0.4 mass %.

[0051]

Alternatively, not only washer 1 but also needle rollers 2 or cage 3 may have a nitrogen enriched layer at the surface layer portion, the amount of retained austenite at the surface layer portion may be at least 5 volume % and at most 25 volume %, and the austenite grain size number at the surface layer portion may be 11 or larger. Nitrogen concentration at the surface layer portion may be at least 0.05 mass % and at most 0.4 mass %.

[0052]

Though a structure in which the needle rollers are arranged in a single row has been described above, the needle rollers may be arranged in a plurality of rows, as shown in Fig. 4.

[0053]

Referring to Fig. 4, the thrust needle roller bearing 10B that corresponds to the thrust needle roller bearing 10 of Figs. 1 and 2 has needle rollers 2 arranged in a plurality of rows, including needle rollers 2a on the inner diameter side and needle rollers 2b on the outer diameter side. Here, cage 3 is preferably formed by two annular plate members 3a and 3b overlapped to be in contact with each other. Preferably, annular

member 3a has an end portion on the inner diameter side bent and crimped to the side of annular member 3b, and annular member 3b has an end portion on the outer diameter side bent and crimped to the side of annular member 3a. In this manner, two annular members 3a and 3b can be fixed by crimping and firmly integrated.

[0054]

Though lengths L1 and L2 of needle rollers 2a and 2b arranged in a plurality of rows are the same in this example, the length may be selected to $L1 \leq L2$ or $L2 \leq L1$, dependent on the conditions of use. It is preferred to increase load carrying capacity on the outer diameter side by making the length L2 of the needle roller 2b on the outer diameter side longer, for example, 1.2 times longer, than the length L1 of the needle roller 2a on the inner diameter side.

[0055]

Except for the point described above, the structure of thrust needle roller bearing 10B is almost the same as that of thrust needle roller bearing 10A described above and, therefore, the same members are denoted by the same reference characters and description thereof will not be repeated.

[0056]

Next, heat treatment including carbonitriding process performed on at least one bearing component of washer 1, needle roller 2 and cage 3 of each of thrust needle roller bearings 10A and 10B in accordance with the present embodiment will be described.

[0057]

Figs. 5 and 6 show the method of heat treatment for forming the thrust needle roller bearing in accordance with the present invention. Fig. 5 shows a pattern of heat treatment representing a method involving primary and secondary quenching. Fig. 6 shows a pattern of heat treatment in which the material is cooled to a temperature lower than A_1 transformation point during quenching and thereafter re-heated for final quenching. Both are examples of heat treatment for the thrust needle roller bearing of the present invention.

[0058]

Referring to Fig. 5, first, steel for a bearing component is heated to a carbonitriding temperature (845°C) not lower than the A_1 transformation point, and at this temperature, carbonitriding process is performed on the steel for the bearing component. At the process temperature T_1 , carbon and nitrogen are diffused to the steel base, and carbon is sufficiently absorbed in steel. Thereafter, the steel for bearing component is subjected to oil quenching from the process temperature T_1 to a temperature lower than A_1 transformation point. Thereafter, tempering at 230°C is performed. The tempering may be omitted.

[0059]

Thereafter, the steel for bearing component is heated again to a temperature (for example, 800°C), which is not lower than the A_1 transformation point and lower than the carbonitriding temperature described above, and kept at the temperature for a process T_2 , subjected to oil quenching from the process temperature T_2 and cooled to a temperature lower than the A_1 transformation point. Then, tempering is performed at 230°C.

[0060]

Referring to Fig. 6, first, steel for a bearing component is heated to a carbonitriding temperature (845°C) not lower than the A_1 transformation point, and at this temperature, carbonitriding process is performed on the steel for the bearing component. At the process temperature T_1 , carbon and nitrogen are diffused to the steel base, and carbon is sufficiently absorbed in steel. Thereafter, the steel for bearing component is not subjected to quenching but cooled to a temperature lower than the A_1 transformation point. Thereafter, the steel for bearing component is heated again to a temperature (for example, 800°C), which is not lower than the A_1 transformation point and lower than the carbonitriding temperature described above, and kept at the temperature for a process T_2 , subjected to oil quenching from the process temperature T_2 and cooled to a temperature lower than the A_1 transformation point. Then,

tempering is performed at 230°C.

[0061]

By the carbonitriding process described above, a nitrogen enriched layer, which is the "carbonitrided layer," is formed at the surface layer portion of the steel for bearing component. In the carbonitriding process, steel as the material has high carbon concentration, and therefore, sometimes carbon does not readily enter the surface of steel from common carbonitriding atmosphere. In steel having high carbon concentration (of about 1 mass %), a carburized layer of higher carbon concentration may or may not be generated. On the other hand, though it depends on Cr (chromium) concentration, nitrogen concentration is as low as about 0.020 mass% in typical steel. Therefore, a nitrogen enriched layer is definitely formed regardless of the carbon concentration of material steel. It is needless to say that the nitrogen enriched layer may also be enriched with carbon.

[0062]

As compared with common quenching (that is, one quenching following carbonitriding process), the heat treatment described above is effective against an early failure caused by surface damage such as surface-originated flaking and also effective against subsurface-originated flaking caused by common rolling contact fatigue dependent on load, while carbonitriding of the surface layer is attained. Therefore, the treatment enables longer life of the thrust needle roller bearing.

[0063]

Fig. 7(a) shows austenite grain size of the bearing steel that has been subjected to the heat treatment pattern shown in Fig. 5. For comparison, Fig. 7(b) shows austenite grain size of the bearing steel that has been subjected to conventional heat treatment. Figs. 8(a) and 8(b) illustrate austenite grain size corresponding to Figs. 7(a) and 7(b). From these textures showing the austenite grain size, it can be seen that the conventional austenite grain size has JIS (Japanese Industrial Standard) grain size number 10, whereas the heat treatment in accordance with the present invention

provides fine grains of number 12. The average grain diameter of Fig. 7(a) measured by the section method was 5.6 μm .

[Examples]

[0064]

Examples of the present invention will be described in the following.

[0065]

Rollers and washers (having the thickness of at most 3 mm) formed of press-processable steel plates and steel tapes of SUJ2 material (JIS: high carbon chromium bearing steel material), SCM415M (JIS: chromium-molybdenum steel) and S70C (JIS: carbon steel material for machine structural purpose) were prepared. Various heat treatments were performed on the washers and rollers. The heat treatments included heat treatments of heating patterns shown in Figs. 5 and 6 (special heat treatment), carbonitriding process, quenching (quench-hardening, high temperature quench-hardening, double quench-hardening) and carburizing process.

[0066]

In the special heat treatment, the objects were kept in a mixed gas atmosphere of an RX gas and an ammonia gas, at 840°C for a prescribed time period for carbonitriding, subjected to primary quenching from that temperature, and tempered at 230°C.

Thereafter, the temperature was again increased to 800°C, which is lower than the carbonitriding temperature, the components were kept at that temperature for a prescribed time period, subjected to secondary quenching, and then tempered at 230°C.

[0067]

In the carbonitriding process, the objects were kept at 840°C for a prescribed time period for carbonitriding, thereafter quenched from that temperature and tempered at 230°C.

[0068]

In the carbonitriding process + quench-hardening process, the objects were kept at 840°C for a prescribed time period for carbonitriding, thereafter quenched from that

temperature and tempered at 230°C. Then, the temperature was again increased to 840°C, the components were kept at that temperature for a prescribed time period, subjected to quenching from this temperature, and tempered at 230°C.

[0069]

In the carburizing process, the objects were kept at 850°C for a prescribed time period for carburization, subjected to quenching from that temperature, and then tempered at 230°C.

[0070]

In the quench-hardening process, the objects were kept at 850°C for a prescribed time period, subjected to quenching from that temperature, and then tempered at 230°C.

[0071]

In the high temperature quench-hardening process, the objects were kept at 880°C for a prescribed time period, subjected to quenching from that temperature, and then tempered at 230°C.

[0072]

In the double quench-hardening process, the objects were kept at 840°C for a prescribed time period, subjected to primary quenching from that temperature, and then tempered at 230°C. Then, the temperature was again increased to 840°C, the objects were kept at that temperature for a prescribed time period, subjected to secondary quenching from that temperature, and tempered at 230°C.

[0073]

Crystal grain size numbers, amount of retained austenite and nitrogen content at the surface layer of the washers subjected to the processes above are as shown in Table 1.

[0074]

Crystal grain size was measured by the method of austenite grain size determination in accordance with JIS G 0551. Average values among ten test samples formed under the same conditions were found.

[0075]

The amount of retained austenite was measured by X-ray diffraction method, at a depth of 0.05 mm from the surface at four positions of the washer surface. Further, average values among ten test samples (10 samples × 4 positions) formed under the same conditions were found.

[0076]

The nitrogen content at the surface layer portion of washers was measured by EPMA analysis, by cutting the washers vertical to the washer surface. Average values of five samples formed under the same conditions were found.

[0077]

[Table 1]

Test Sample Materials

| | Materials and heat treatments of washers | Grain size (No.) | Amount of retained austenite (vol%) | Nitrogen content of surface layer (mass%) |
|---------------------|---|------------------|-------------------------------------|---|
| Present invention | SUJ2 special heat treatment | 12.5 | 8.2 | 0.25 |
| | SCM415M special heat treatment | 12.0 | 22.2 | 0.29 |
| | S70C special heat treatment | 11.5 | 15.4 | 0.27 |
| Comparative Example | SUJ2 carbonitriding | 10.5 | 28 | 0.28 |
| | SCM415M carbonitriding | 10.0 | 32.4 | 0.33 |
| | SCM415M carbonitriding + quench-hardening | 11.0 | 27.6 | 0.31 |
| | S70C carbonitriding | 9.5 | 26.6 | 0.3 |
| | SUJ2 quench-hardening | 10.0 | 4.2 | 0 |
| | SCM415M carburizing | 9.5 | 28.2 | 0 |
| | S70C quench-hardening | 9.5 | 3.8 | 0 |
| | SUJ2 high temp. quench-hardening | 9.0 | 10.8 | 0 |
| | SUJ2 double quench-hardening | 11.5 | 4.0 | 0 |

[0078]

As can be seen from the results shown in Table 1, in all test samples of washers subjected to special heat treatment formed of SUJ2, SCM415M and S70C, a nitrogen enriched layer was observed at the surface layer portion, the grain size number of

austenite at the surface layer portion was 11 or higher, amount of retained austenite was at least 5 volume % and at most 25 volume %, and nitrogen content at the surface layer portion was at least 0.1 mass % and at most 0.7 mass %.

[0079]

The test samples subjected to heat treatments other than the special heat treatment cannot attain one of or both of austenite grain size number of 11 or higher and amount of retained austenite of at least 5 volume % and at most 25 volume %.

[0080]

Then, thrust needle roller bearings were formed by combining each of the washers described above with rollers, and life test of the thrust needle roller bearings was conducted. The conditions of life test are as shown in Table 2, and the test results are as shown in Table 3.

[0081]

[Table 2]

Test Conditions

| | |
|-------------------|---|
| Load | 4000N |
| Speed of Rotation | 8000 r/min |
| Lubrication | Mission oil circulating lubrication, natural warming |

[0082]

[Table 3]

| Example | No. | Characteristics | Life ratio (L10) |
|---------------------|-----|--|------------------|
| Present invention | 1 | washer, roller: SUJ2 special heat treatment | 17.2 |
| | 2 | washer: SUJ2 special heat treatment roller: SUJ2 carbonitriding | 16.5 |
| | 3 | washer: SCM415M special heat treatment roller: SUJ2 special heat treatment | 10.8 |
| | 4 | washer: SCM415M special heat treatment roller: SUJ2 carbonitriding | 8.5 |
| | 5 | washer: S70C special heat treatment roller: SUJ2 special heat treatment | 14.2 |
| | 6 | washer: S70C special heat treatment roller: SUJ2 carbonitriding | 13.1 |
| Comparative Example | 7 | washer: SCM415M carbonitriding roller: SUJ2 carbonitriding | 3.0 |
| | 8 | washer: SCM415M carbonitriding + quench-hardening roller: SUJ2 carbonitriding | 3.3 |
| | 9 | washer: SCM415M carbonitriding roller: SUJ2 quench-hardening | 1.5 |
| | 10 | washer, roller: SUJ2 carbonitriding | 4.2 |
| | 11 | washer: S70C carbonitriding roller: SUJ2 carbonitriding | 3.4 |
| | 12 | washer: SCM415M carburizing roller: SUJ2 carbonitriding | 1.0 |
| | 13 | washer: SCM415M carburizing roller: SUJ2 quench-hardening | 0.5 |
| | 14 | washer: SUJ2 quench-hardening roller: SUJ2 carbonitriding | 0.9 |
| | 15 | washer: SUJ2 high temperature quench-hardening roller: SUJ2 carbonitriding | 1.0 |
| | 16 | washer: SUJ2 double quench-hardening roller: SUJ2 carbonitriding | 0.9 |
| | 17 | washer: SUJ2 quench-hardening roller: SUJ2 quench-hardening | 0.4 |
| | 18 | washer: S70C quench-hardening roller: SUJ2 quench-hardening | 0.4 |

* Special heat treatment: developed heat treatment

[0083]

As can be seen from the result of Table 3, the thrust needle roller bearings having washers subjected to the special heat treatment have improved L10 life (number of loaded operation at which 90 % of sample thrust needle roller bearings could be used

without breakage), and have longer life, as compared with thrust needle roller bearings having washers not subjected to the special heat treatment. Where washers and rollers are of the same material, it can be seen that L10 life can further be improved when not only washers but rollers are subjected to the special heat treatment.

[0084]

The embodiments as have been described here are mere examples and should not be interpreted as restrictive. The scope of the present invention is determined by each of the claims with appropriate consideration of the written description of the embodiments and embraces modifications within the meaning of, and equivalent to, the languages in the claims.

[Brief Description of the Drawings]

[Fig. 1] A schematic cross sectional view showing a support structure for a continuously variable transmission in accordance with Embodiment 1 of the present invention.

[Fig. 2] A cross sectional view showing, in enlargement, a portion P of Fig. 1.

[Fig. 3] A schematic cross sectional view showing a structure of a thrust needle roller bearing in accordance with an embodiment of the present invention.

[Fig. 4] A schematic cross sectional view showing a structure of a thrust needle roller bearing having rollers arranged in a plurality of rows, in accordance with another embodiment of the present invention.

[Fig. 5] An illustration of a method of heat treatment of the thrust needle roller bearing in accordance with the present invention.

[Fig. 6] An illustration of a modification of the method of heat treatment of the thrust needle roller bearing in accordance with the present invention.

[Fig. 7] Views showing micro-texture, particularly austenite grains of the bearing component, in which (a) corresponds to the bearing component in accordance with the present invention, and (b) corresponds to a conventional bearing component.

[Fig. 8] Illustration (a) corresponding to Fig. 7(a), showing austenite grain

boundaries, and illustration (b) corresponding to Fig. 7(b), showing austenite grain boundaries.

[Description of the Reference Characters]

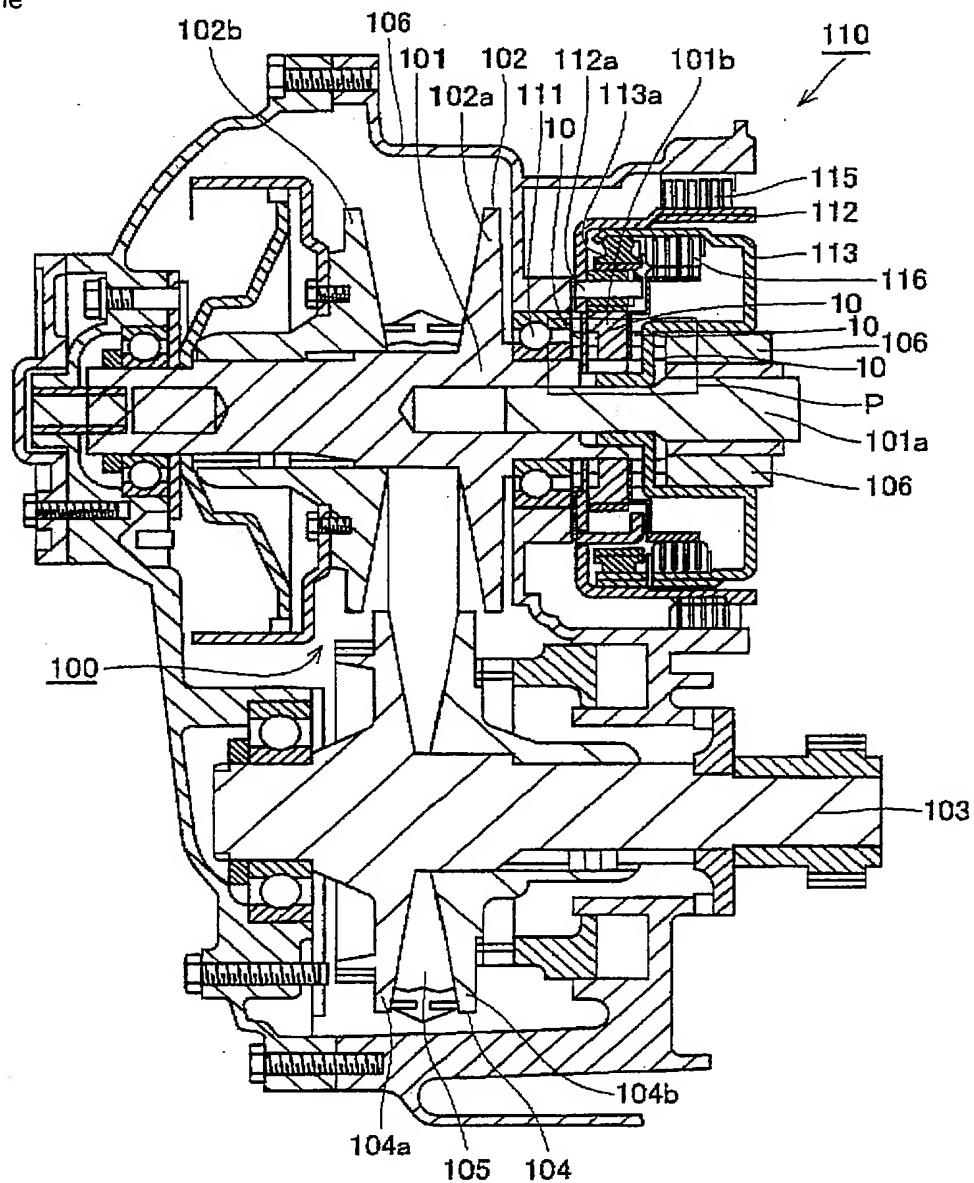
[0086]

1 washer, 1a through hole, 2, 2a, 2b needle roller, 3, 4 cage, 3a, 3b annular member, 10, 10A, 10B thrust needle roller bearing, 100 continuously variable transmission, 101 primary shaft, 101a shaft, 101b sun gear, 102 primary pulley, 102a fixed pulley, 102b movable pulley, 103 secondary shaft, 104 secondary pulley, 104a fixed pulley, 104b movable pulley, 105 belt, 106 housing, 110 forward/backward switching mechanism, 111 roller bearing, 112 support member, 112a planetary pinion, 113 support member, 113a ring gear, 115, 116 multiple disk clutch.

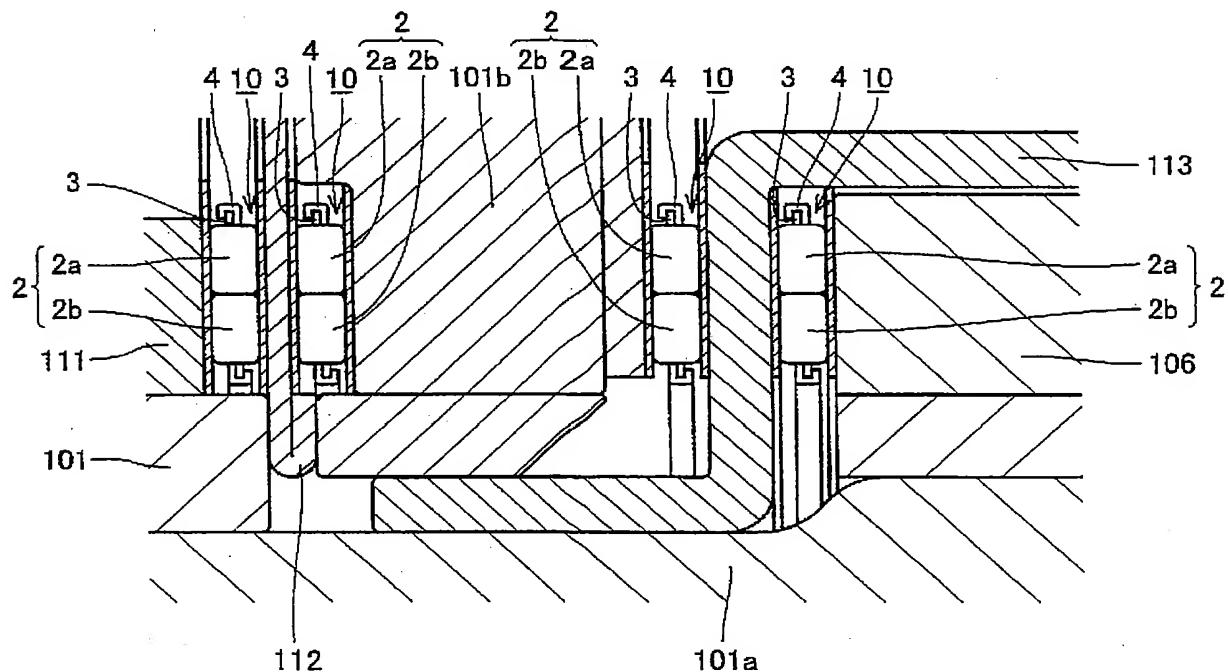
【書類名】 図面 drawings

【図 1】 document
name

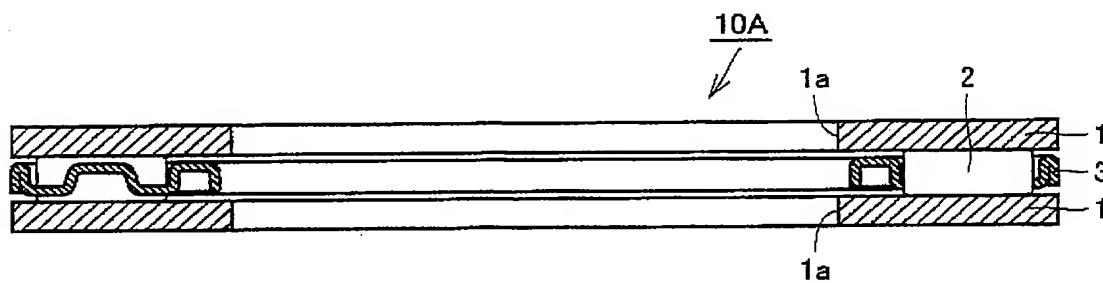
Fig. 1



【図 2】 Fig. 2



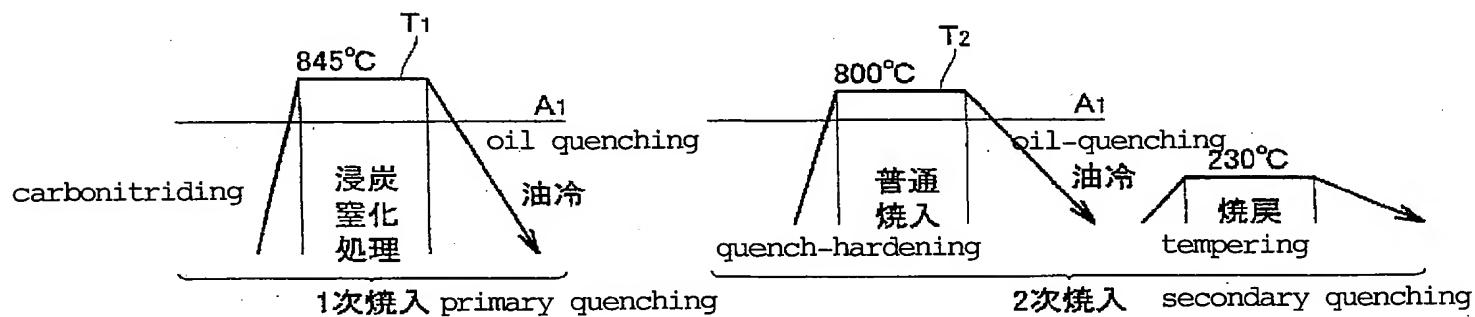
【図 3】 Fig. 3



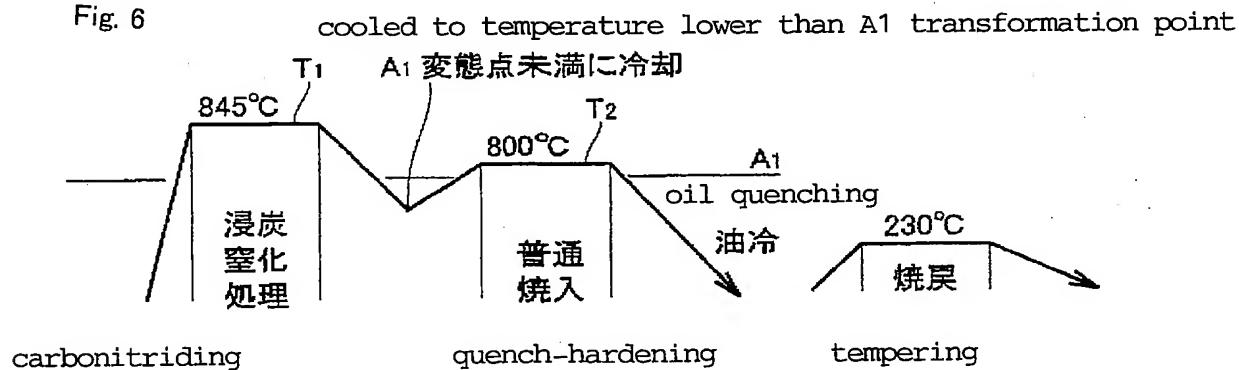
【図 4】 Fig. 4



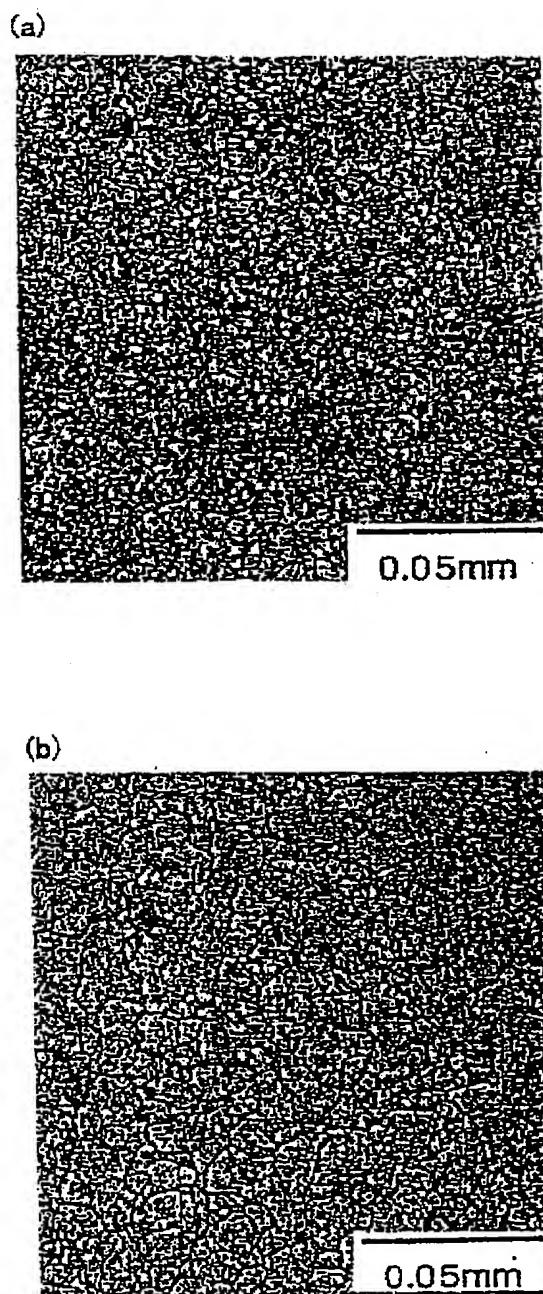
【図 5】 Fig. 5



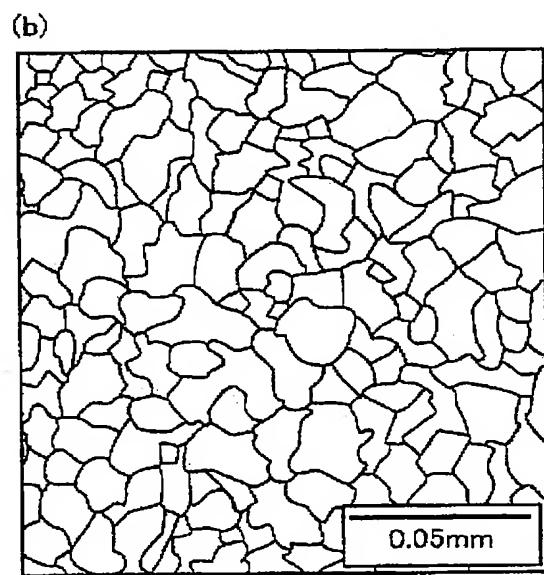
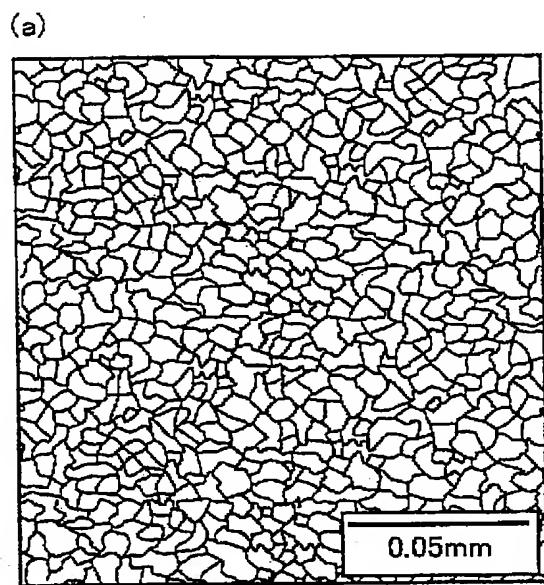
【図 6】 Fig. 6



【図 7】 Fig. 7



【図8】 Fig. 8



[Document Name] Abstract

[Abstract]

[Subject] An object is to provide a long life support structure for a continuously variable transmission, of which thrust needle roller bearing is resistant to an early failure caused by surface damage such as surface-originated flaking and resistant also to common load-dependent rolling contact fatigue.

[Solving Means] A support structure for a continuously variable transmission in which rotation of an input shaft (primary shaft 101, shaft 101a) is changed in a nonstep manner and transmitted to an output shaft (secondary shaft 103), including a thrust needle roller bearing 10 receiving thrust load generated by the rotation either of the input shaft or the output shaft, having a washer 1 formed of a thin steel plate and a needle roller 2, wherein at least the washer 1 has a nitrogen enriched layer at a surface layer portion, amount of retained austenite in said surface layer portion is at least 5 volume % and at most 25 volume %, and austenite grain size number of said surface layer portion is 11 or higher.

[Selected Drawing] Fig. 1